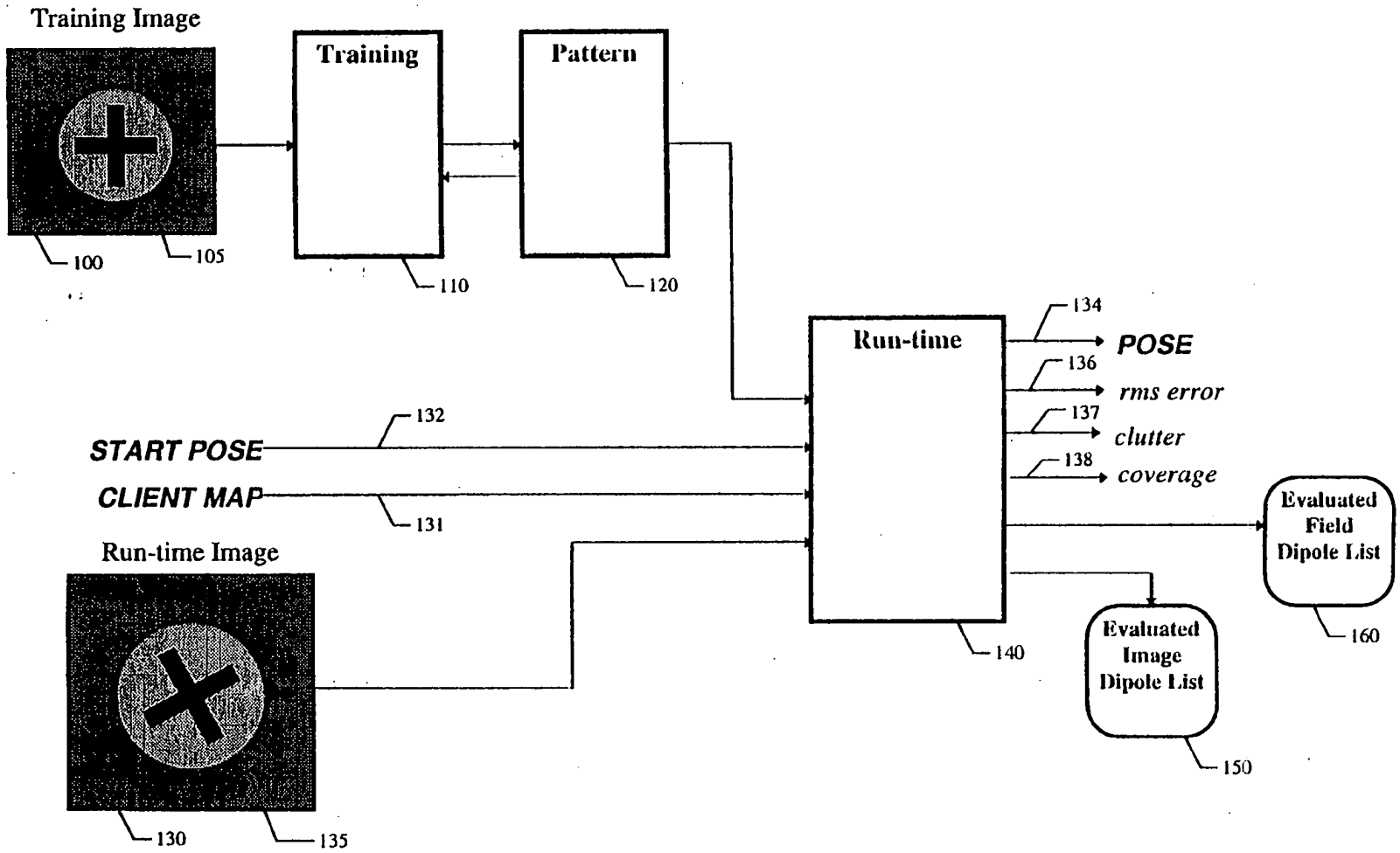
Training Image
Training
Pattern
100
105
110
120
Run-time
134
POSE
136
rms error
137
clutter
138
coverage
132
START POSE
CLIENT MAP
131
Run-time Image
Evaluated Field Dipole List
160
Evaluated Image Dipole List
140
150
130
135

Figure 1

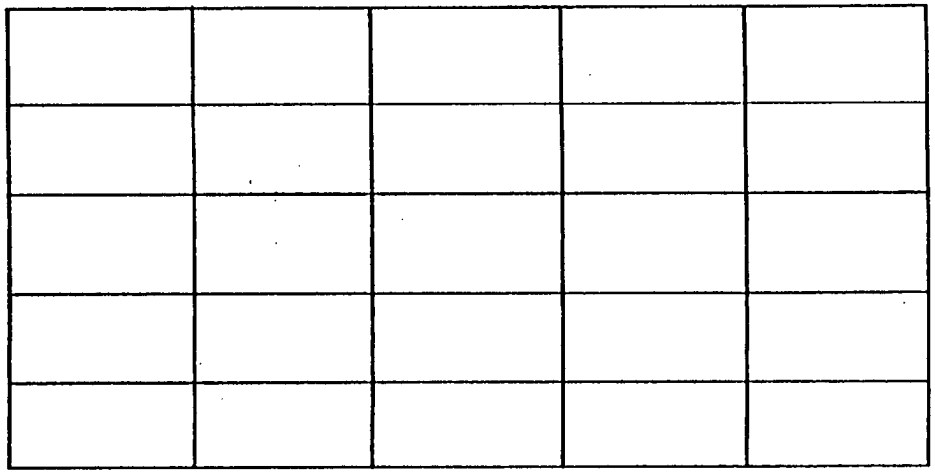

Figure 1a

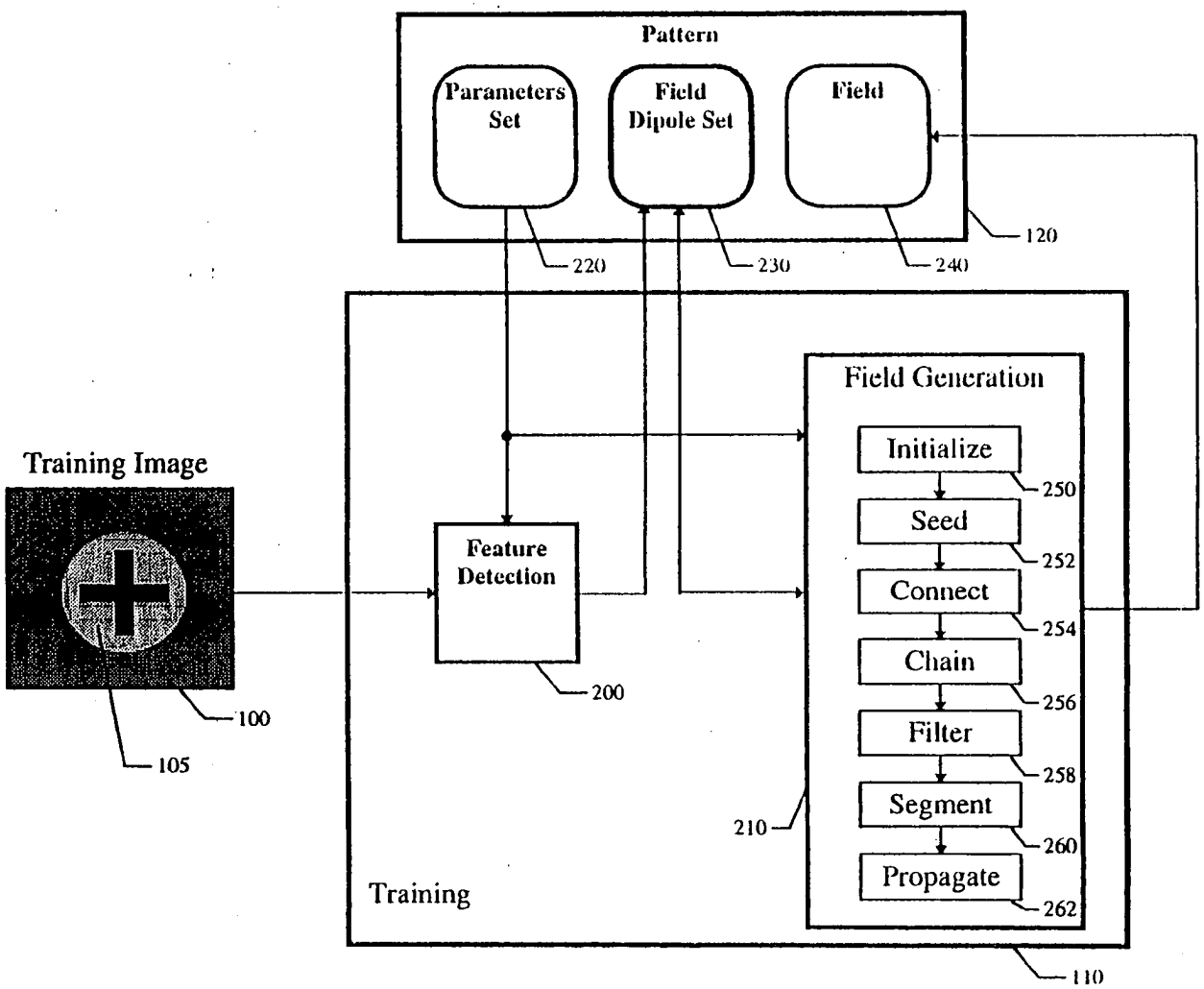
Pattern
Parameters Set
Field Dipole Set
Field
120
220
230
240
Training Image
100
105
Feature Detection
200
Field Generation
Initialize
250
Seed
252
Connect
254
Chain
256
Filter
258
Segment
260
Propagate
262
210
Training
110

Figure 2

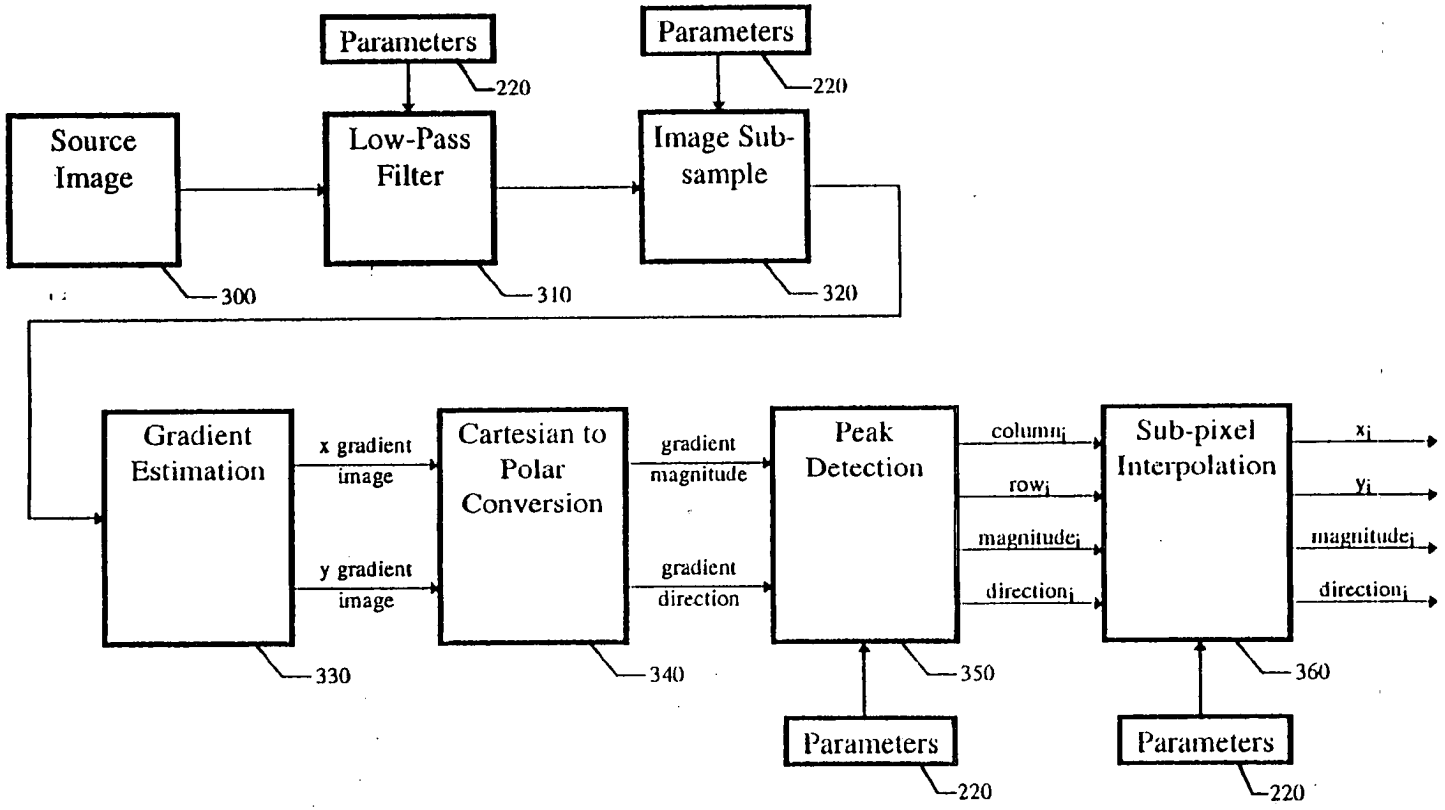
Parameters
220
Parameters
220
Source Image
Low-Pass Filter
Image Sub-sample
300
310
320
Gradient Estimation
x gradient image
y gradient image
Cartesian to Polar Conversion
gradient magnitude
gradient direction
Peak Detection
column$_j$
row$_j$
magnitude$_j$
direction$_j$
Sub-pixel Interpolation
x_j
y_j
magnitude$_j$
direction$_j$
330
340
350
360
Parameters
220
Parameters
220

Figure 3

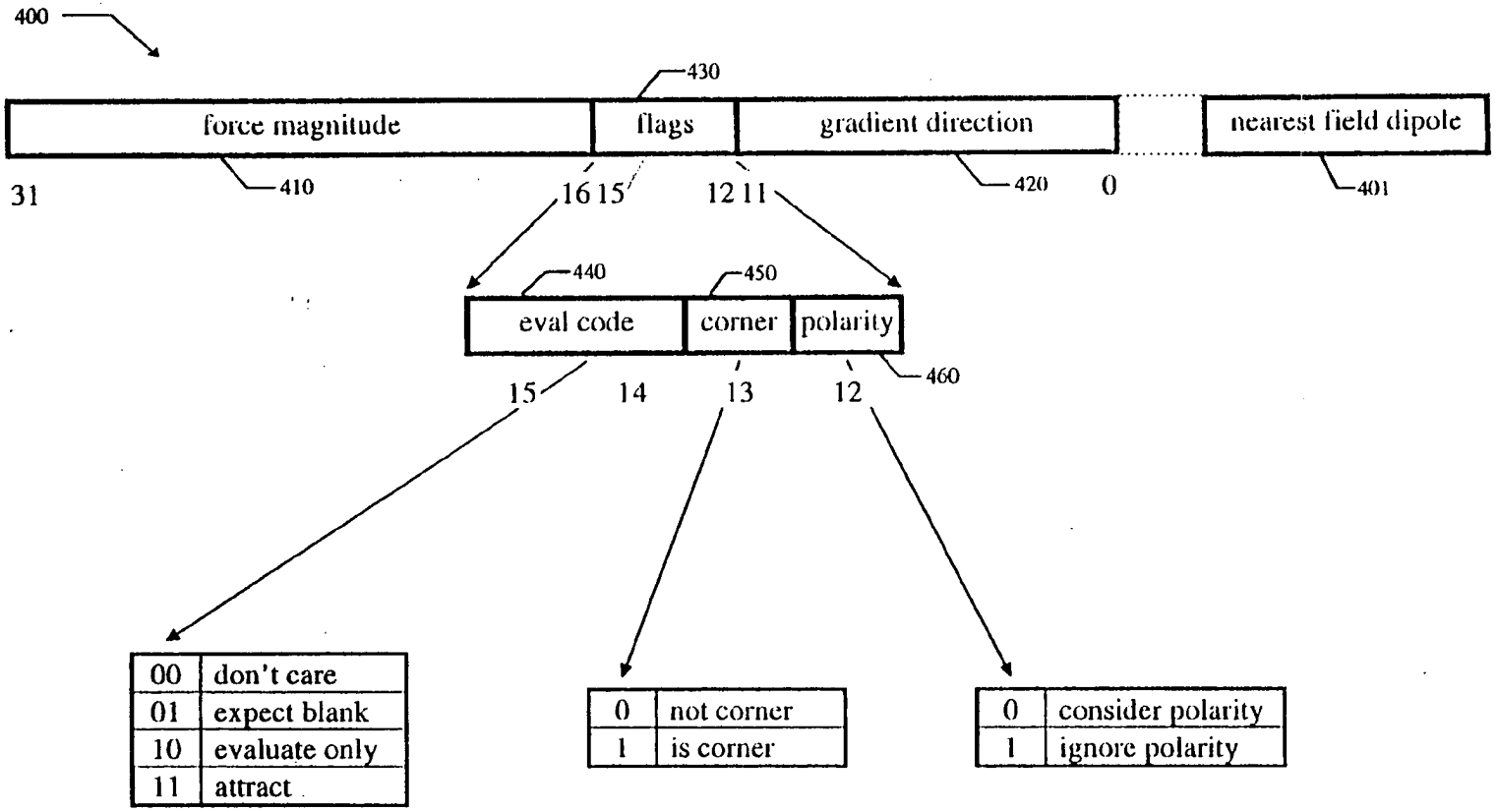
400
430
force magnitude
flags
gradient direction
nearest field dipole
31
410
16 15
12 11
420
0
401
440
450
eval code
corner
polarity
460
15
14
13
12
00 don't care
01 expect blank
10 evaluate only
11 attract
0 not corner
1 is corner
0 consider polarity
1 ignore polarity

Figure 4

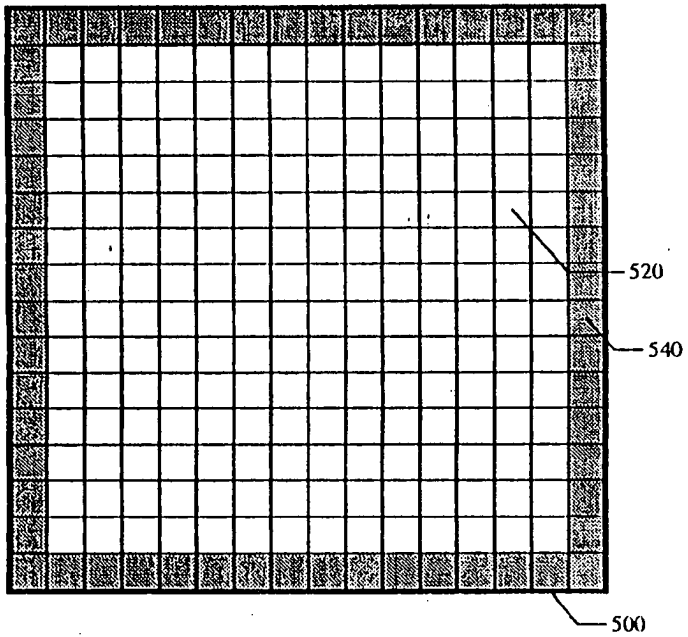

Figure 5

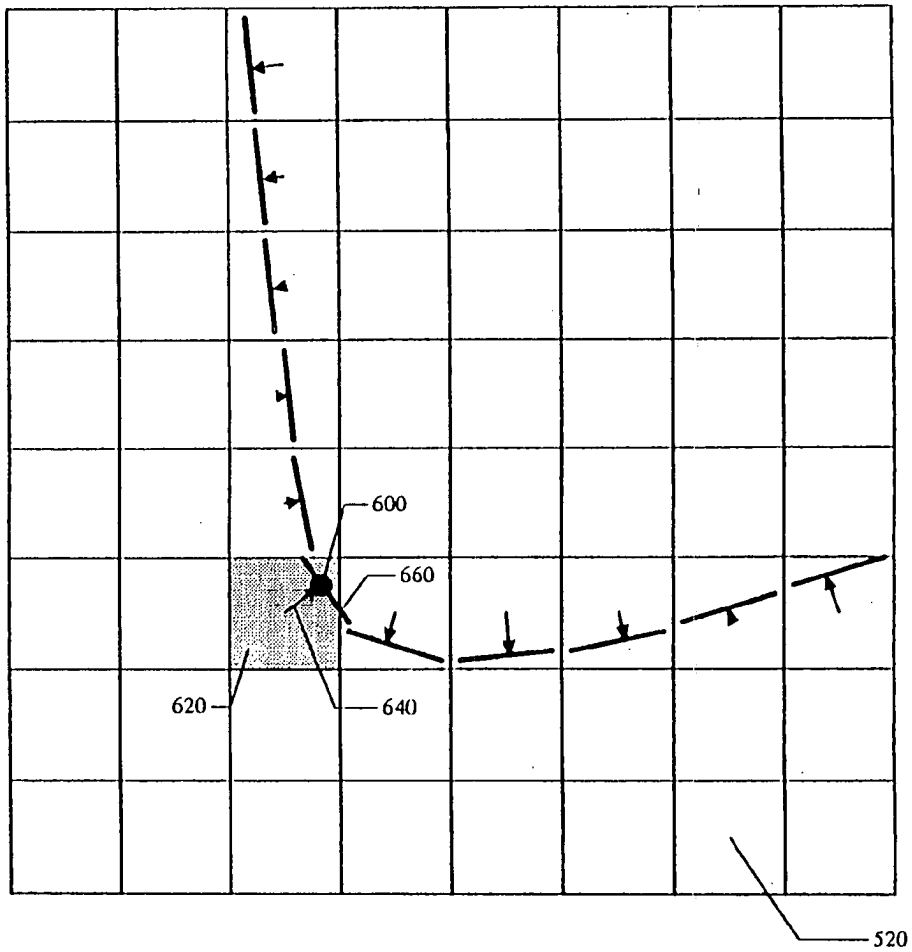

Figure 6

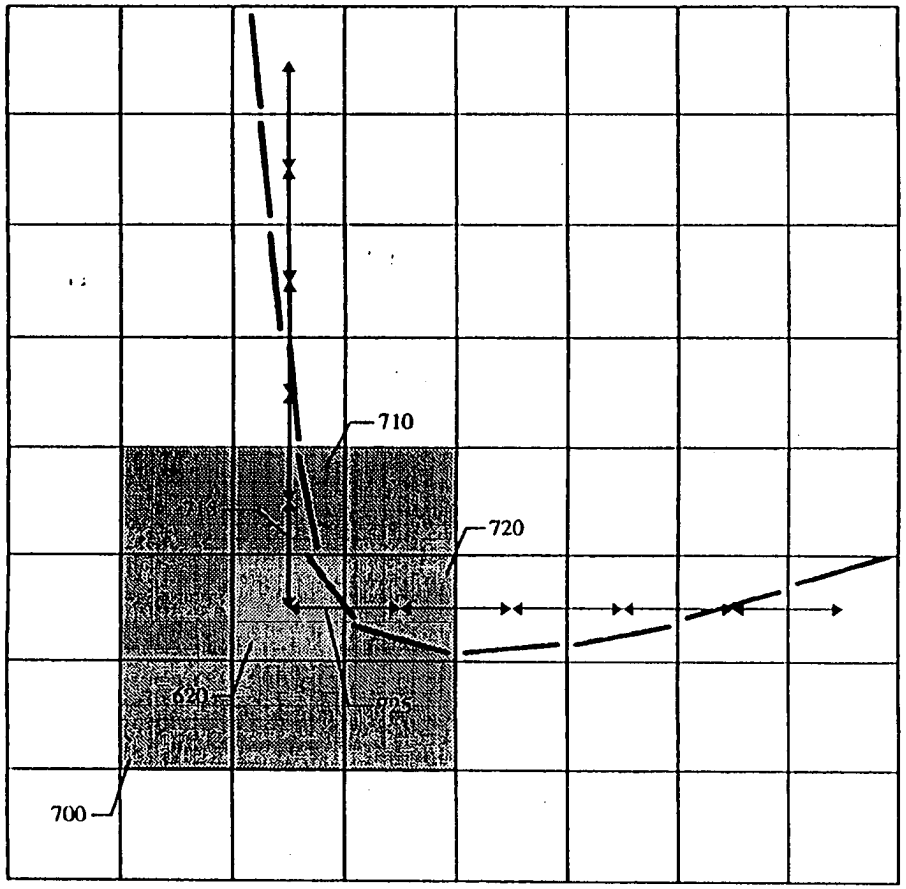

Figure 7a

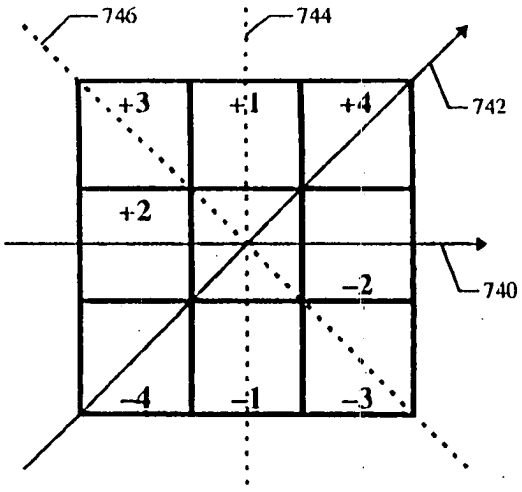

Figure 7b

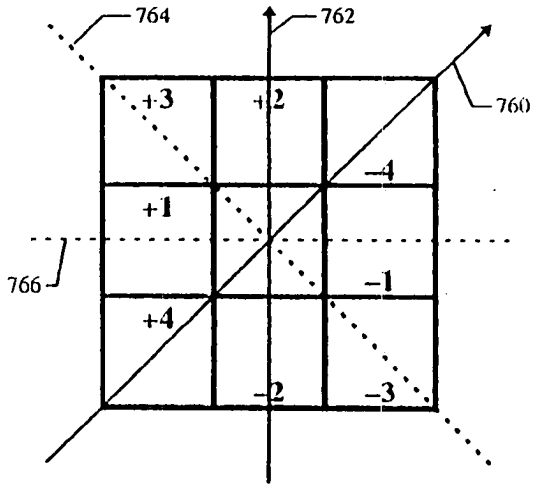

Figure 7c

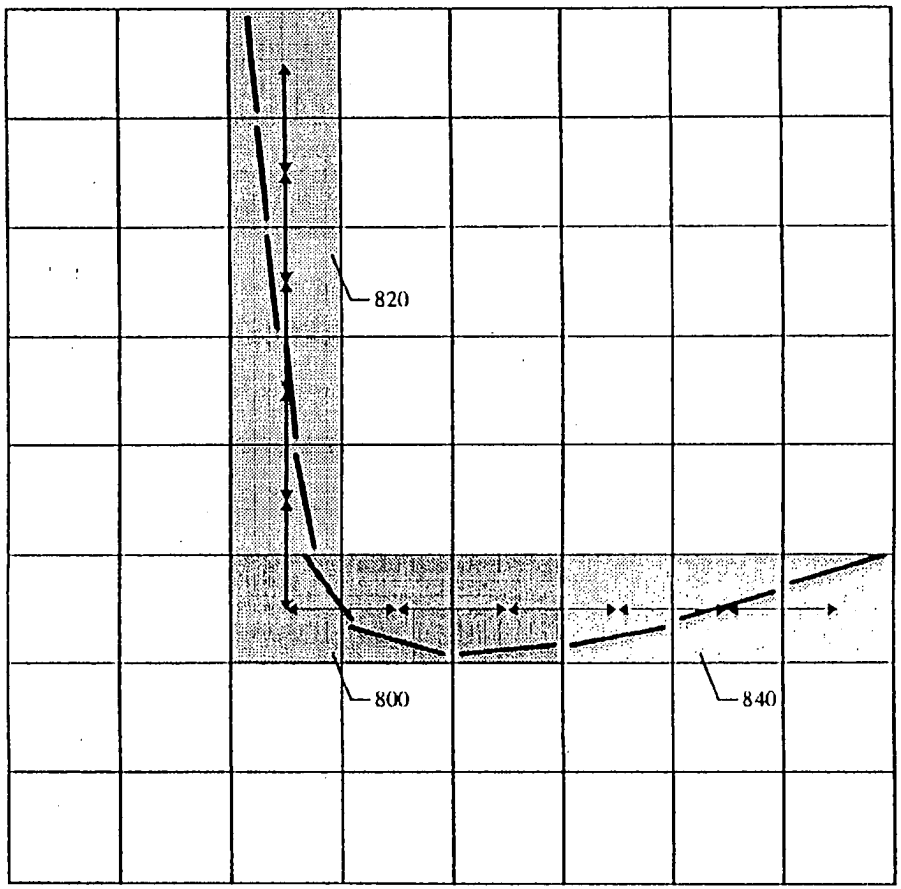

Figure 8

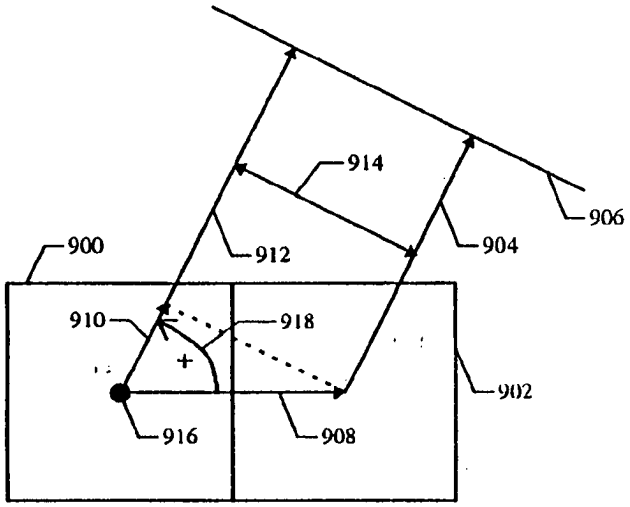

Figure 9a

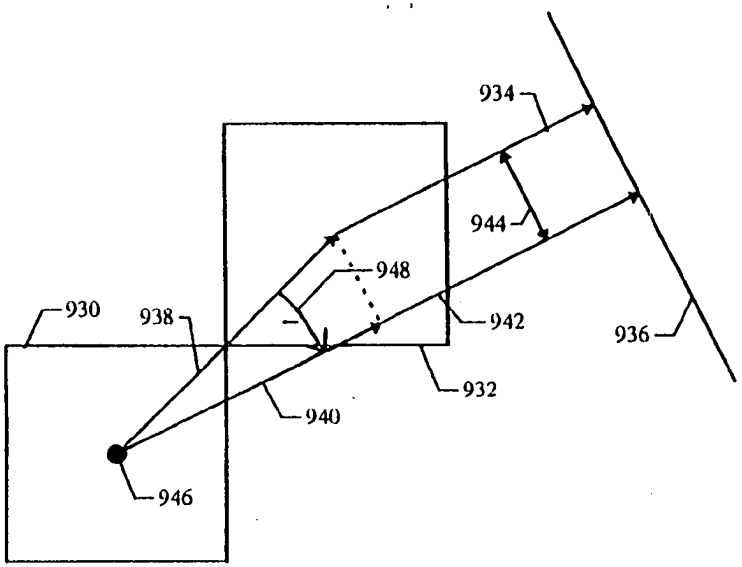

Figure 9b

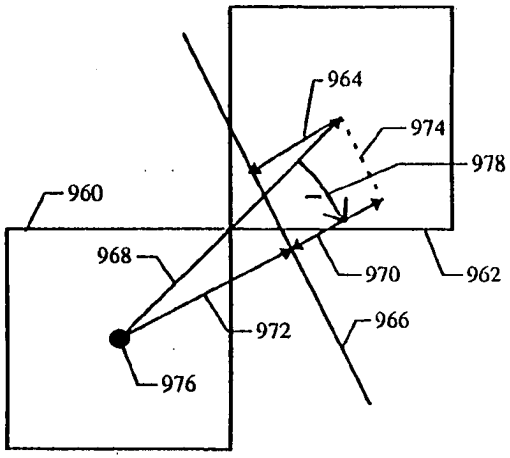

Figure 9c

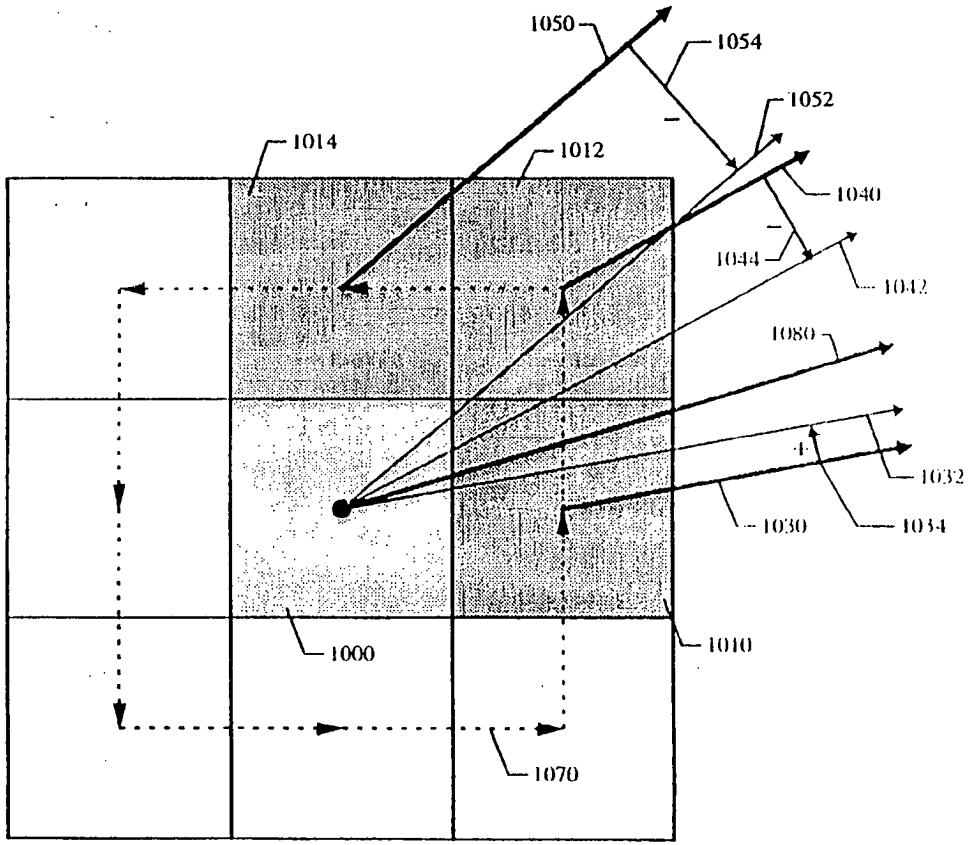
1050
1054
1052
1014
1012
1040
1044
1042
1080
1032
1030
1034
1000
1010
1070

Figure 10

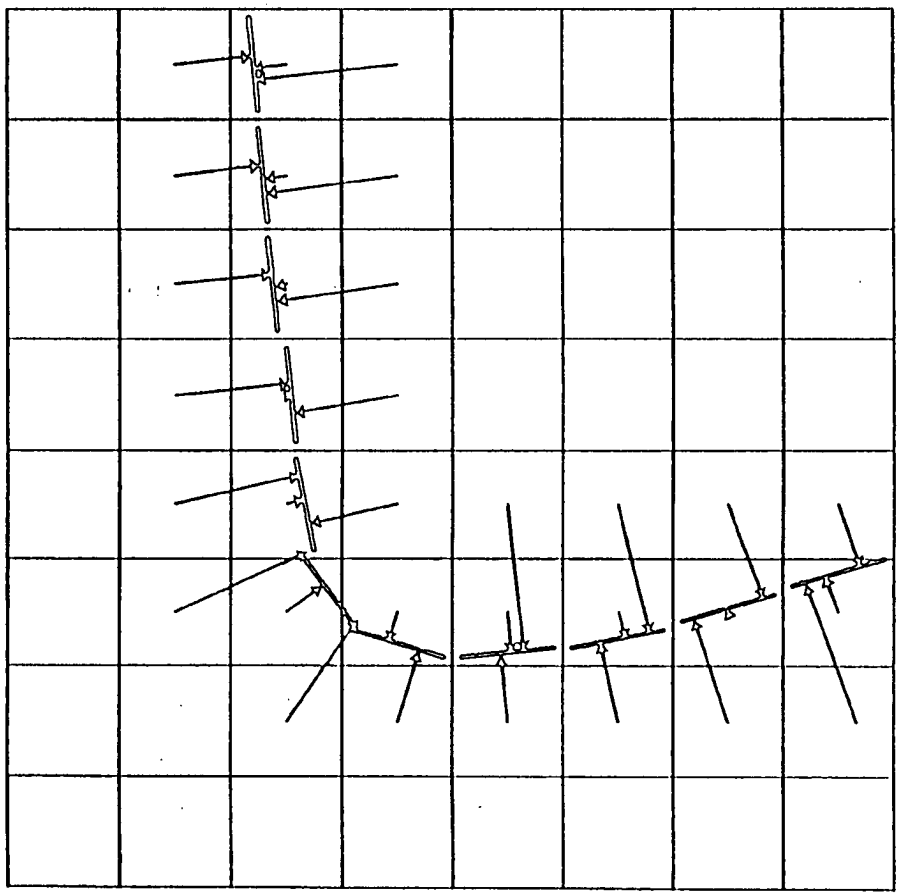

Figure 11

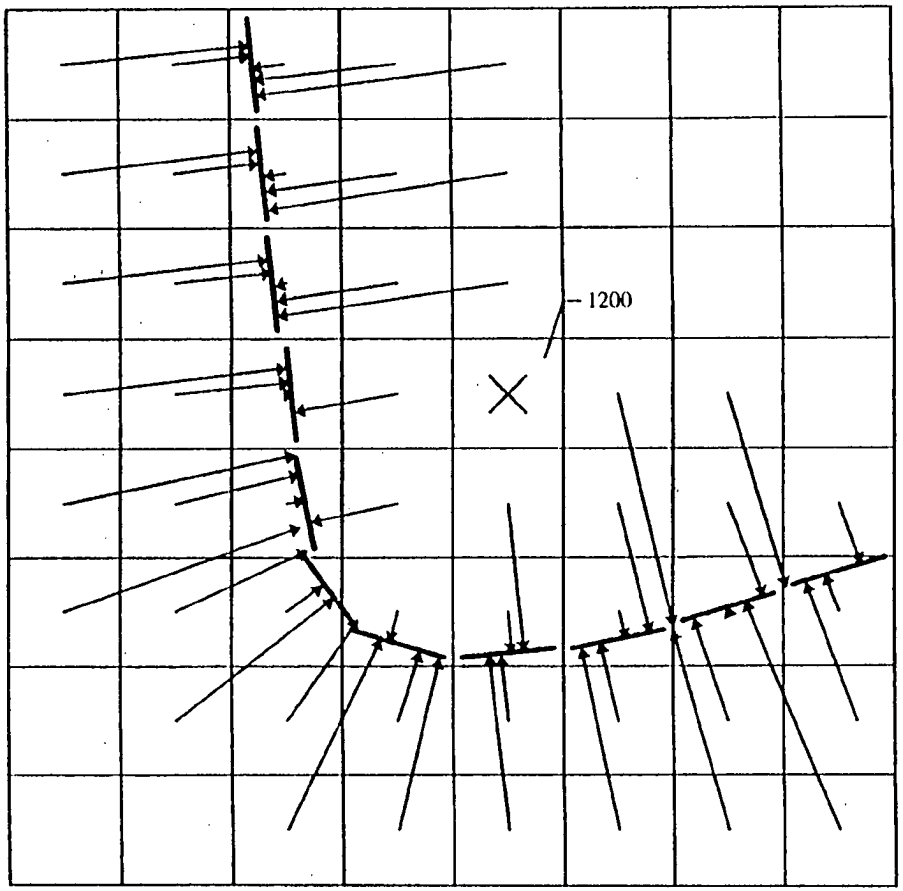

Figure 12

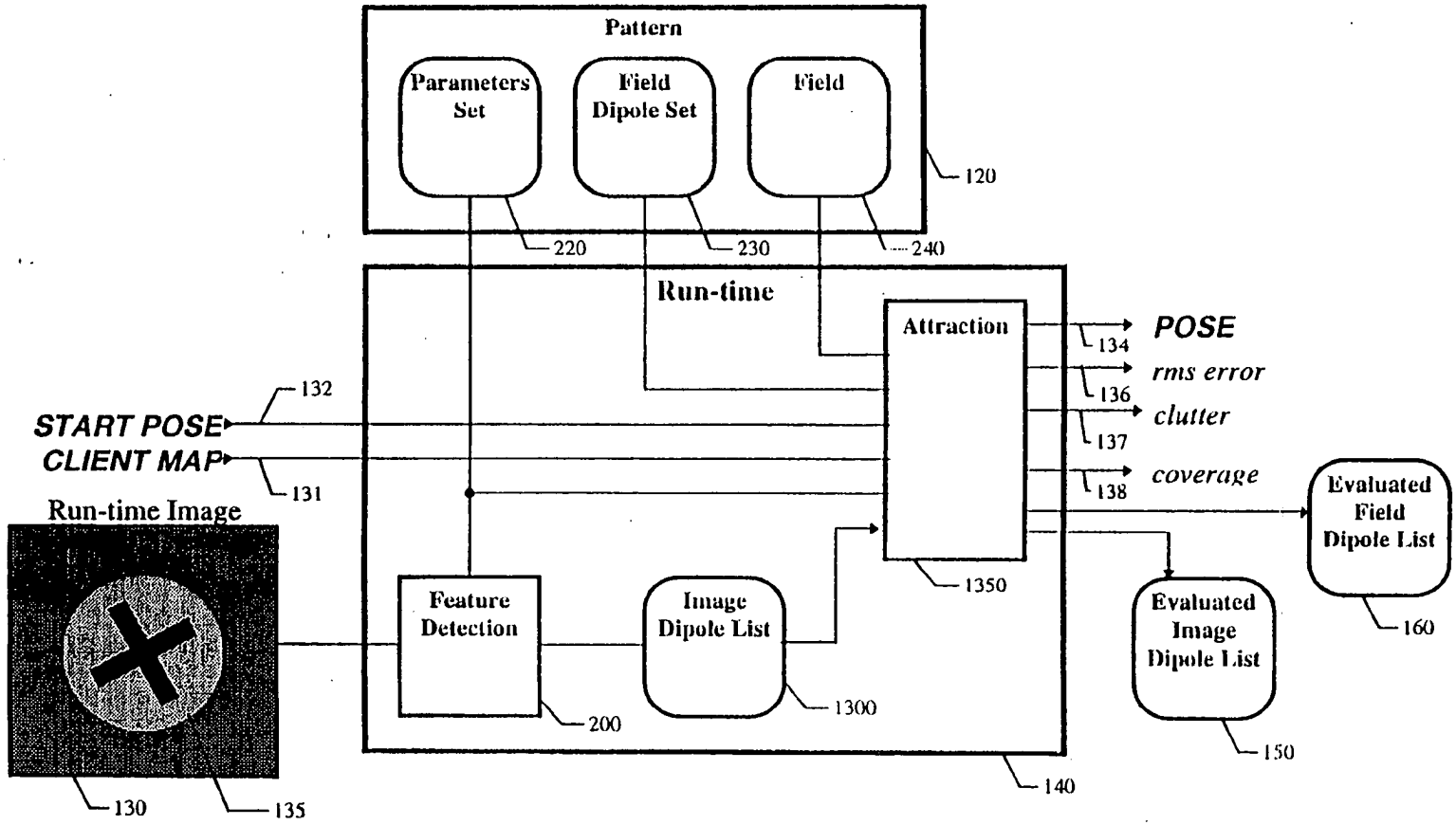
Pattern
Parameters Set
Field Dipole Set
Field
120
220
230
240
Run-time
Attraction
POSE
134
rms error
136
clutter
137
coverage
138
132
START POSE
CLIENT MAP
131
Run-time Image
Feature Detection
Image Dipole List
1350
Evaluated Field Dipole List
160
Evaluated Image Dipole List
150
200
1300
140
130
135

Figure 13

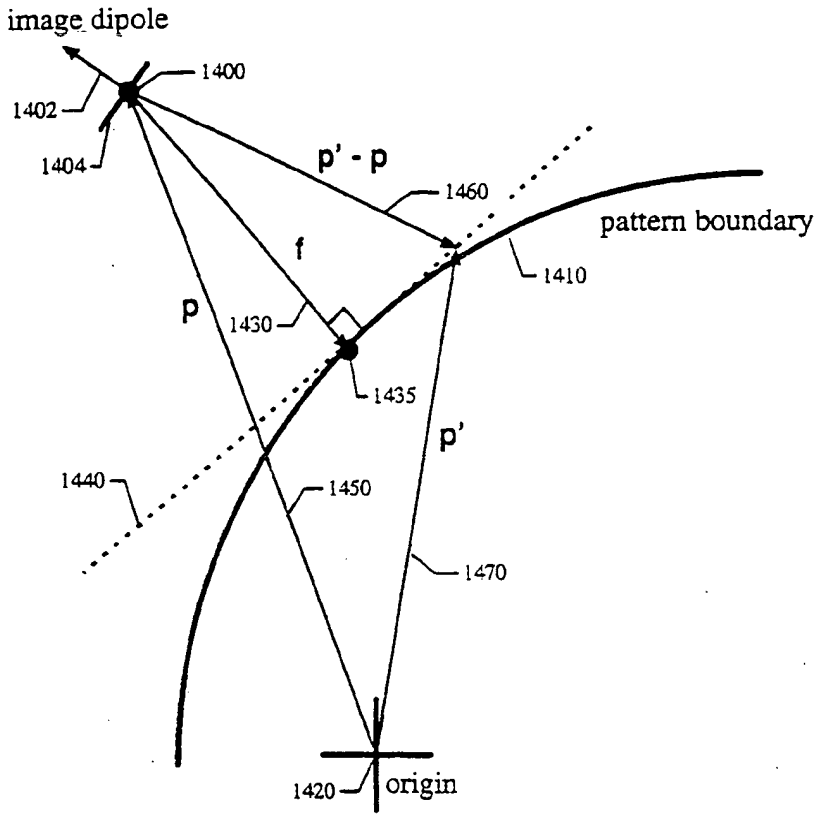
image dipole
1400
1402
1404
p' - p
1460
pattern boundary
f
1410
p
1430
1435
p'
1440
1450
1470
1420
origin

Figure 14

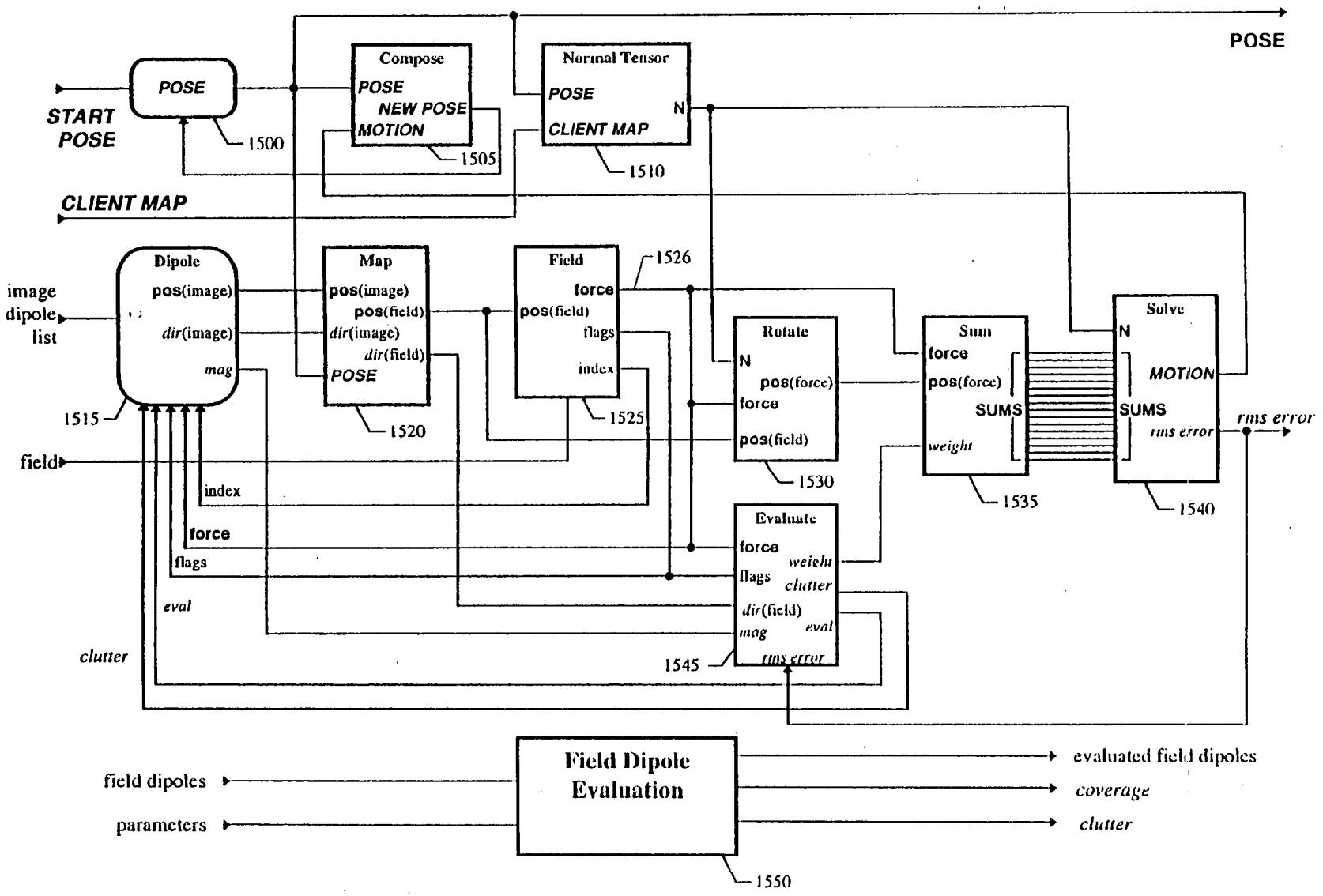
POSE
START POSE
POSE
1500
Compose
POSE
NEW POSE
MOTION
1505
Normal Tensor
POSE
CLIENT MAP
N
1510
CLIENT MAP
image dipole list
Dipole
pos(image)
dir(image)
mag
1515
Map
pos(image)
pos(field)
dir(image)
dir(field)
POSE
1520
Field
force
pos(field)
flags
index
1525
1526
field
index
force
flags
eval
clutter
Rotate
N
pos(force)
force
pos(field)
1530
Sum
force
pos(force)
SUMS
weight
1535
Solve
N
MOTION
SUMS
rms error
1540
rms error
Evaluate
force
flags
dir(field)
mag
weight
clutter
eval
rms error
1545
field dipoles
parameters
Field Dipole Evaluation
1550
evaluated field dipoles
coverage
clutter

Figure 15

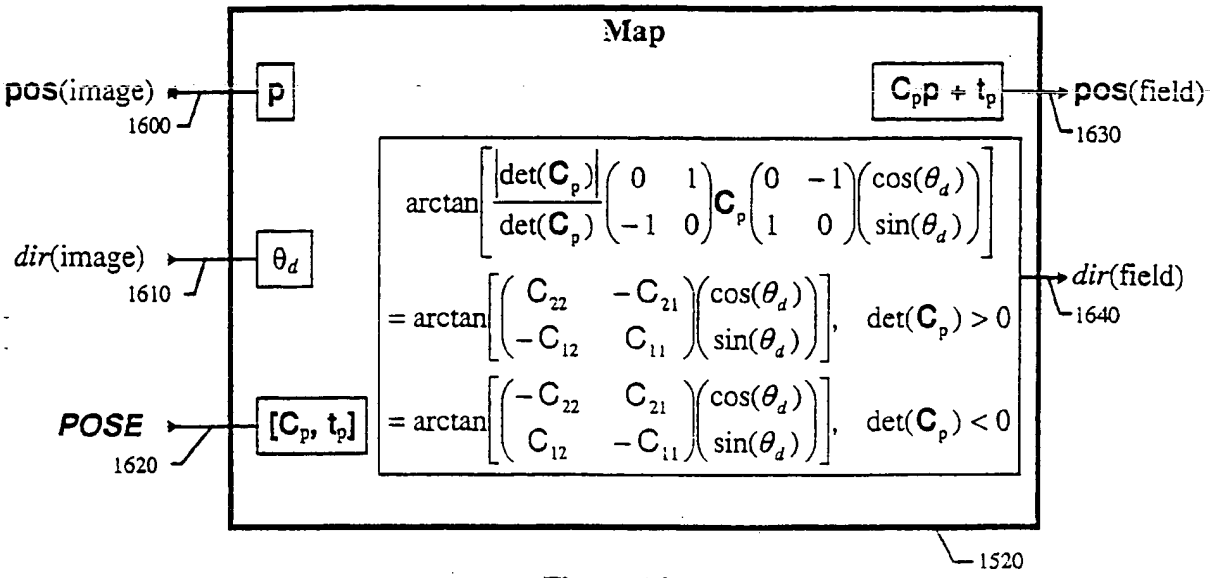

Figure 16

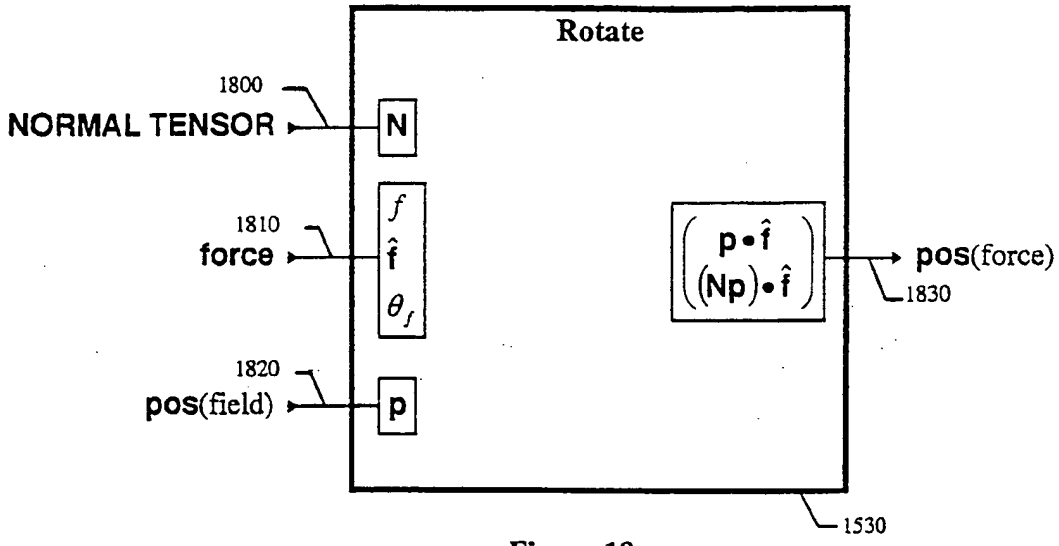

Figure 18

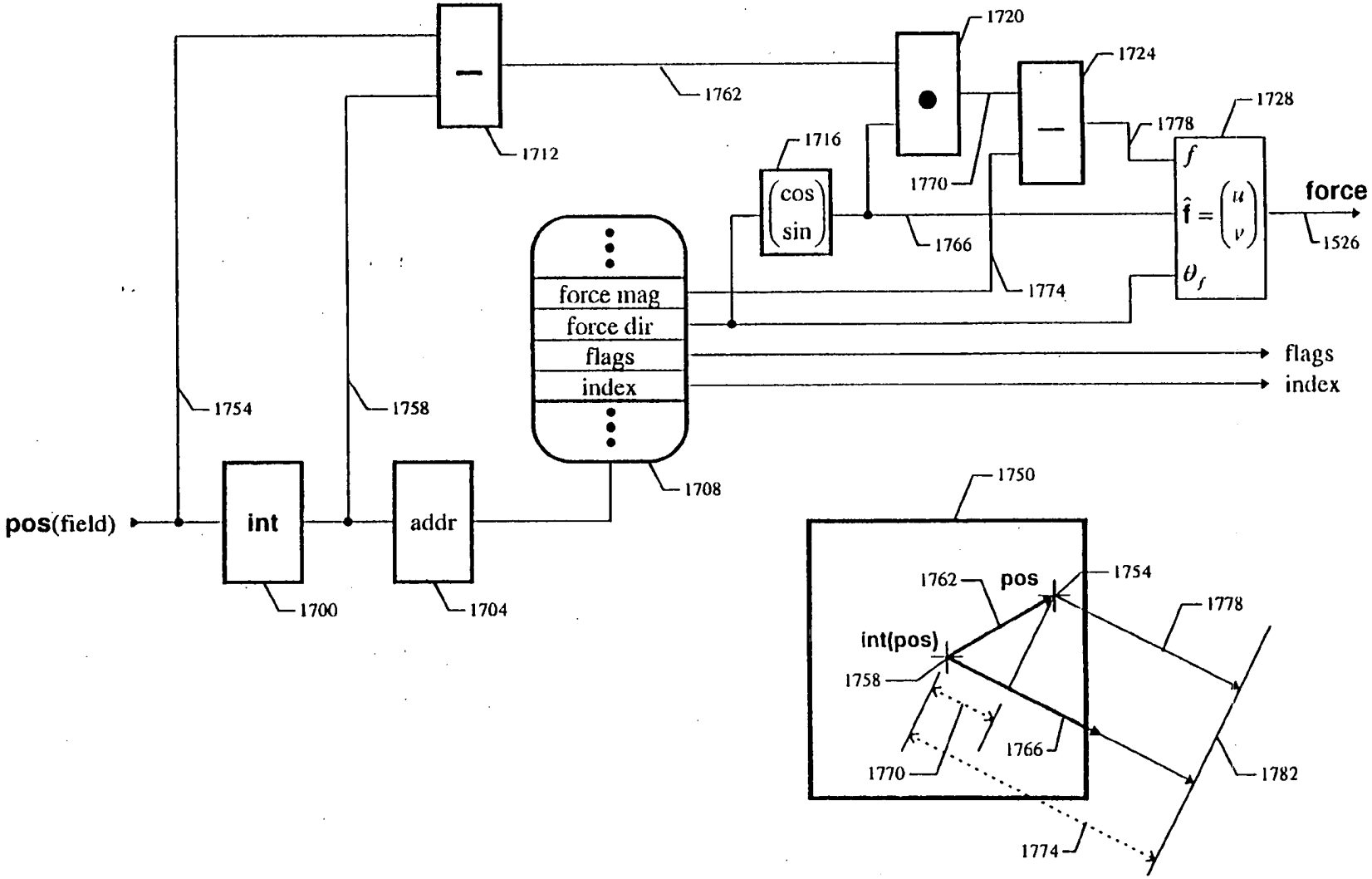
1720
1724
1762
1728
1778
1712
1716
1770
force
1766
1774
1526
force mag
force dir
flags
index
flags
index
1754
1758
1708
pos(field)
int
addr
1700
1704
1750
1762
pos
1754
1778
int(pos)
1758
1766
1770
1782
1774

Figure 17

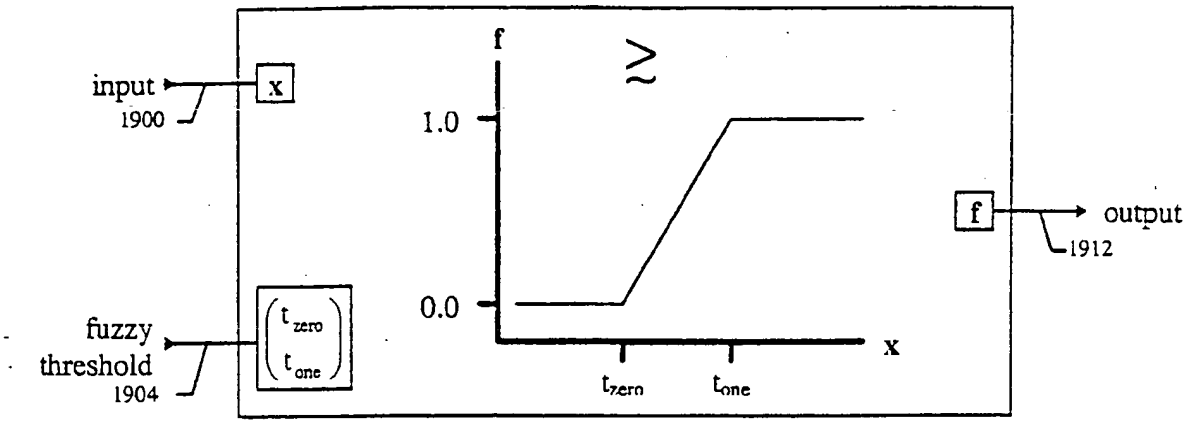

Figure 19a

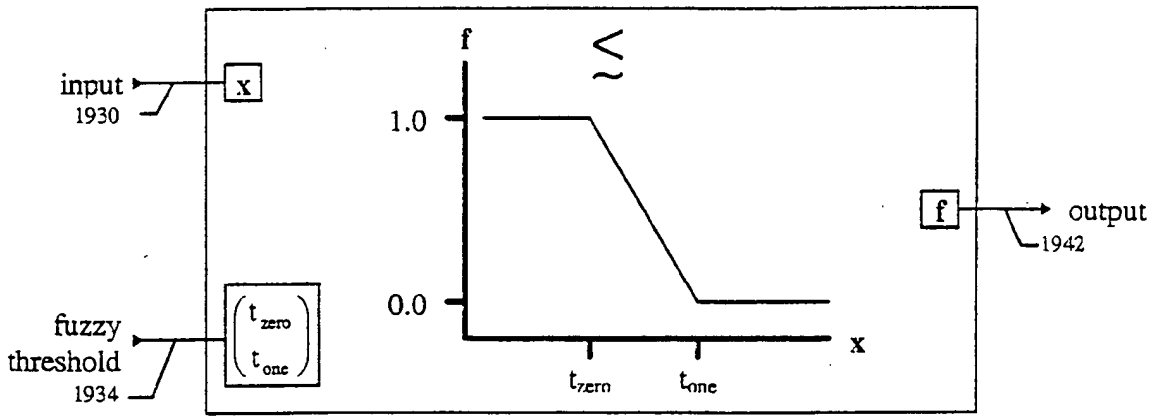

Figure 19b

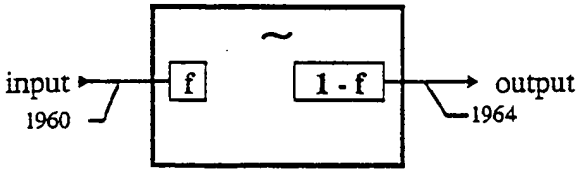

Figure 19c

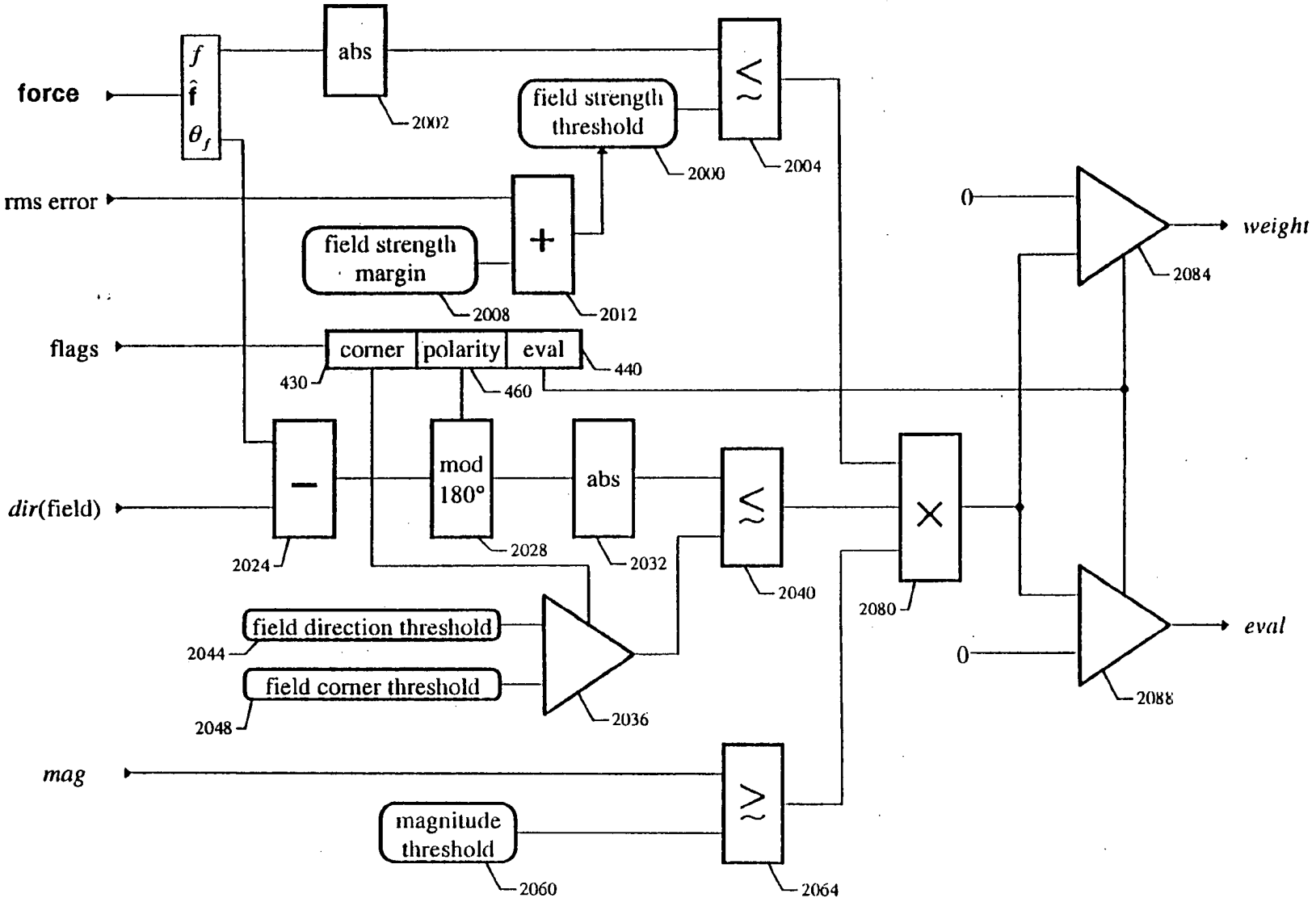
force
f
f̂
θ_f
abs
2002
field strength threshold
2000
≲
2004
rms error
+
field strength margin
2008
2012
flags
corner
polarity
eval
430
460
440
dir(field)
−
mod 180°
abs
2024
2028
2032
≲
2040
×
2080
0
weight
2084
0
eval
2088
field direction threshold
2044
field corner threshold
2048
2036
mag
≳
magnitude threshold
2060
2064

Figure 20a

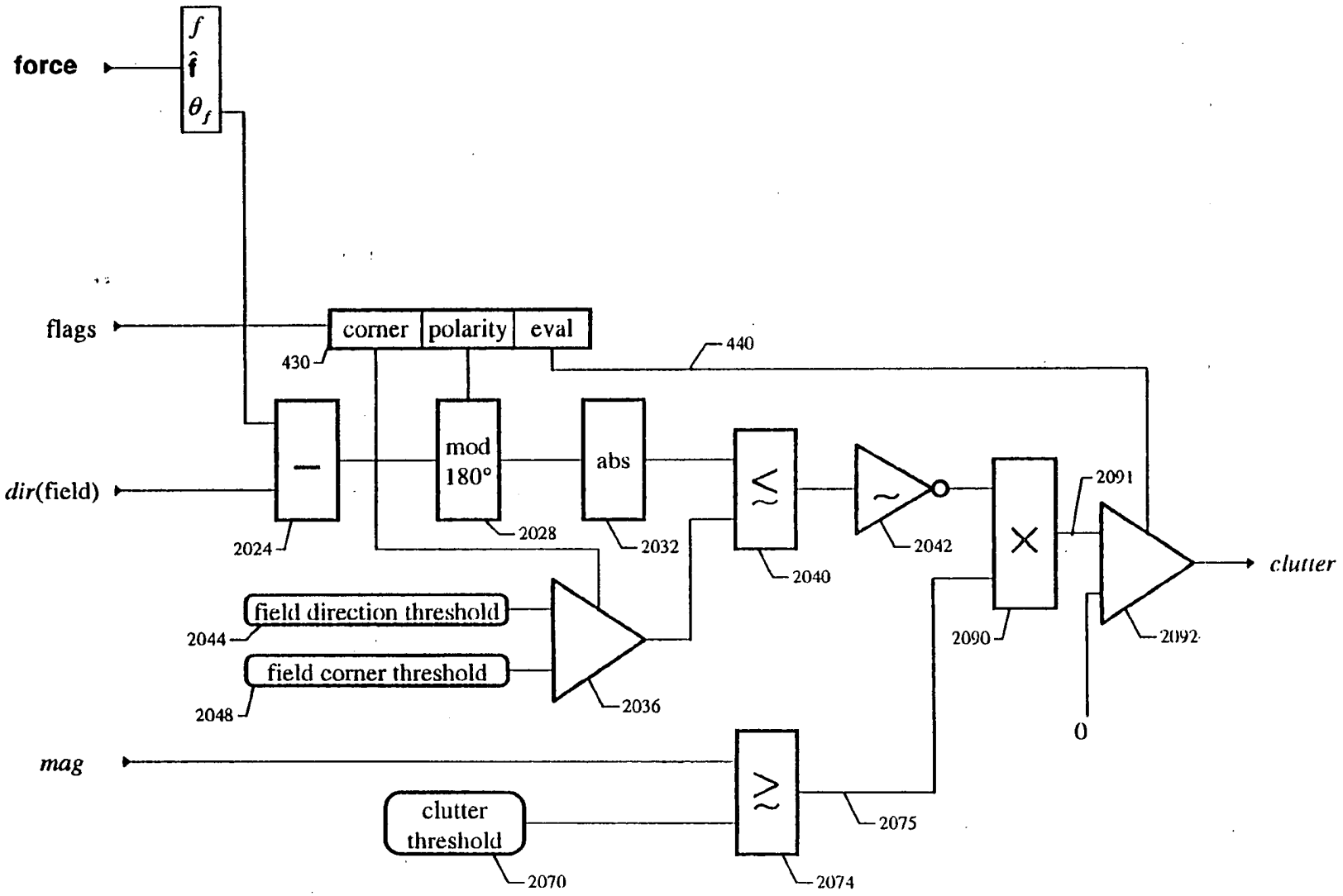
force
f
$\hat{\mathbf{f}}$
θ_f
flags
corner
polarity
eval
430
440
dir(field)
—
mod 180°
abs
≤≈
~
×
2091
2024
2028
2032
2040
2042
2090
2092
clutter
field direction threshold
2044
field corner threshold
2048
2036
0
mag
clutter threshold
2070
≥≈
2074
2075

Figure 20b

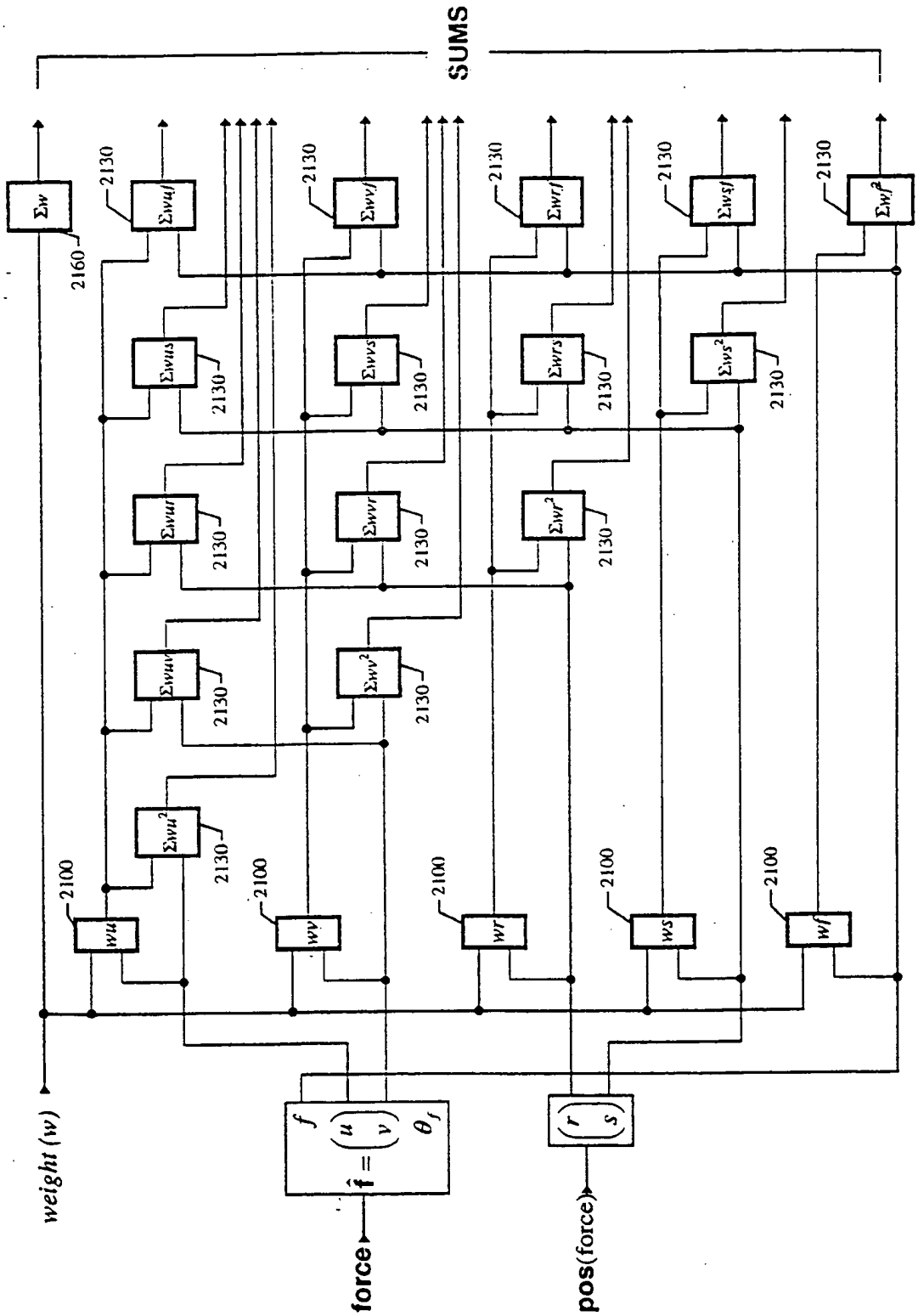

Figure 21

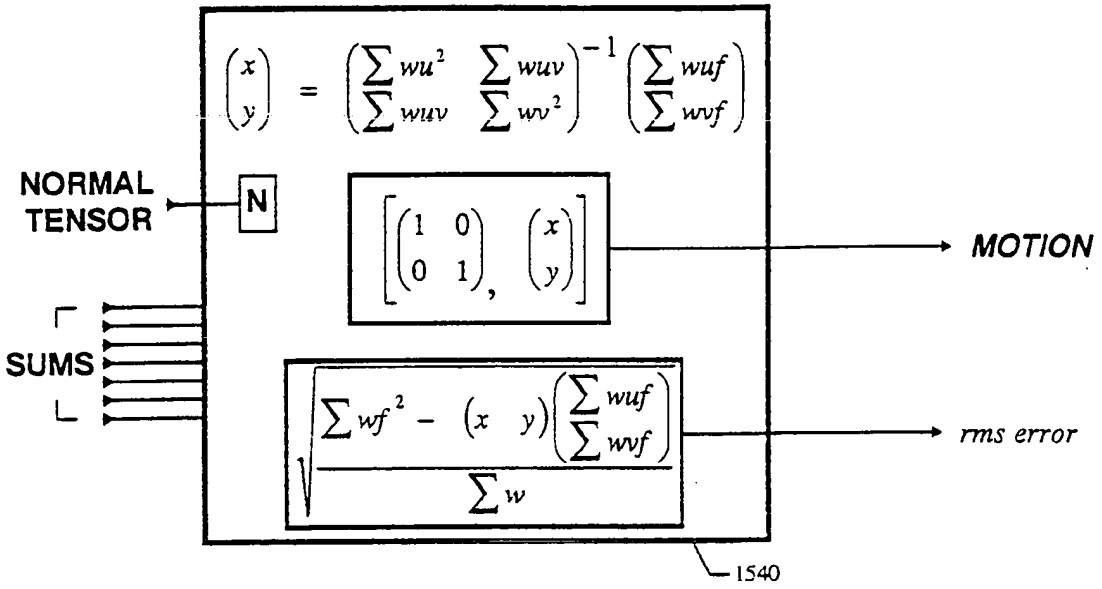

Figure 22a

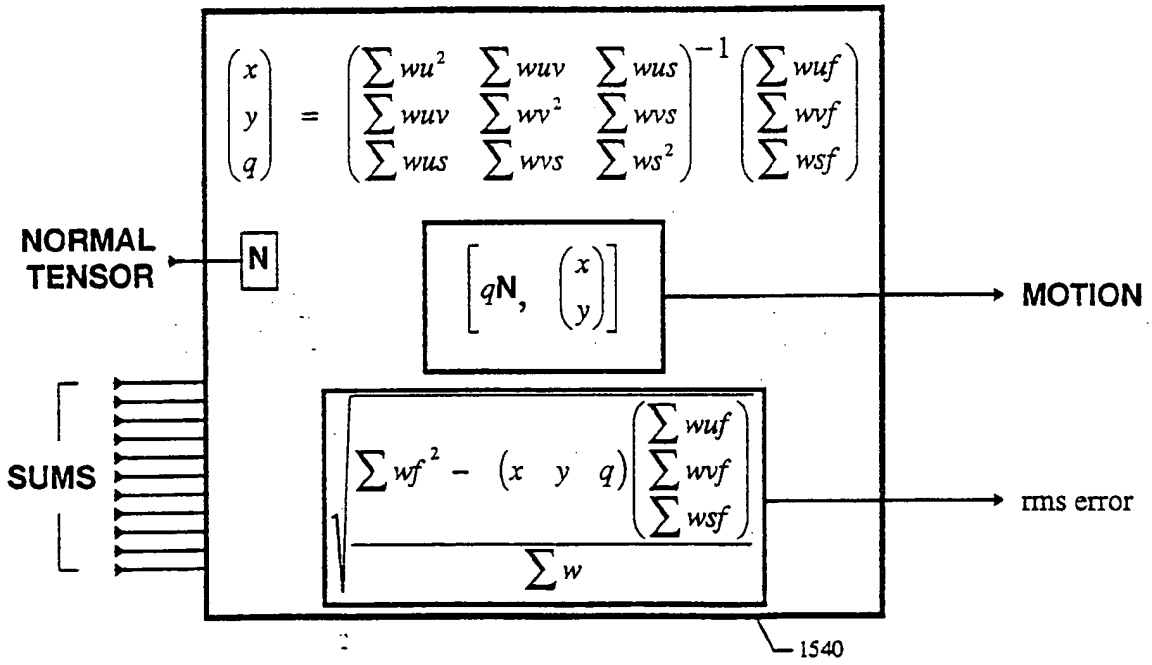

Figure 22b

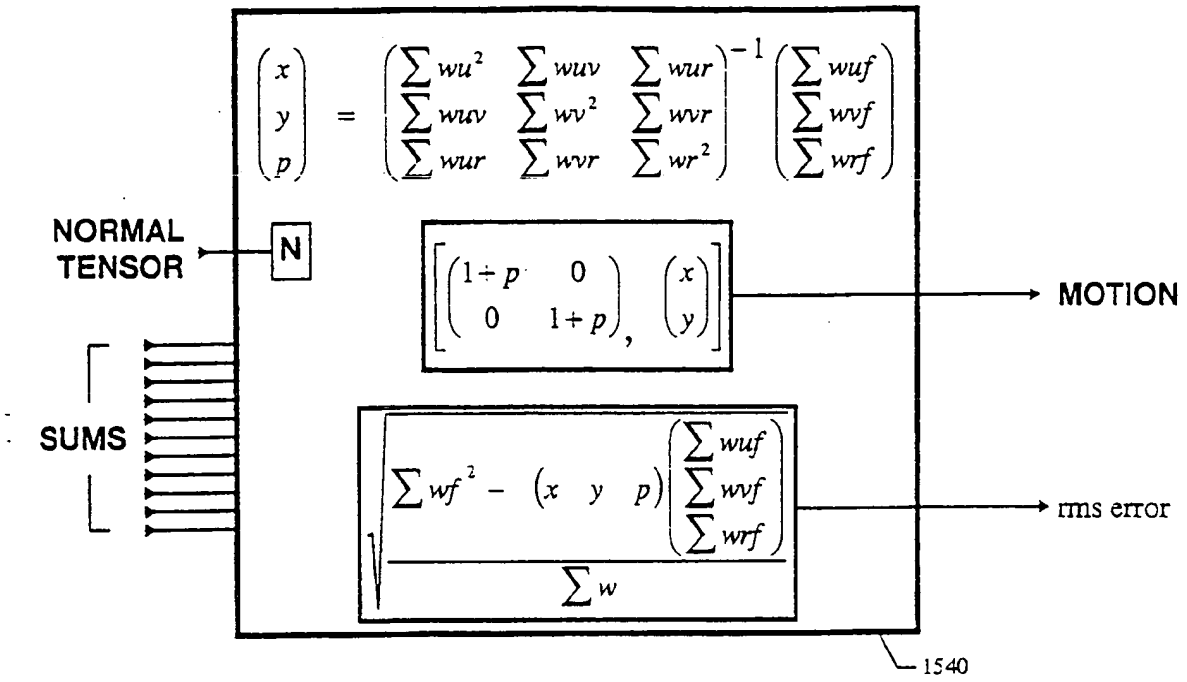

Figure 22c

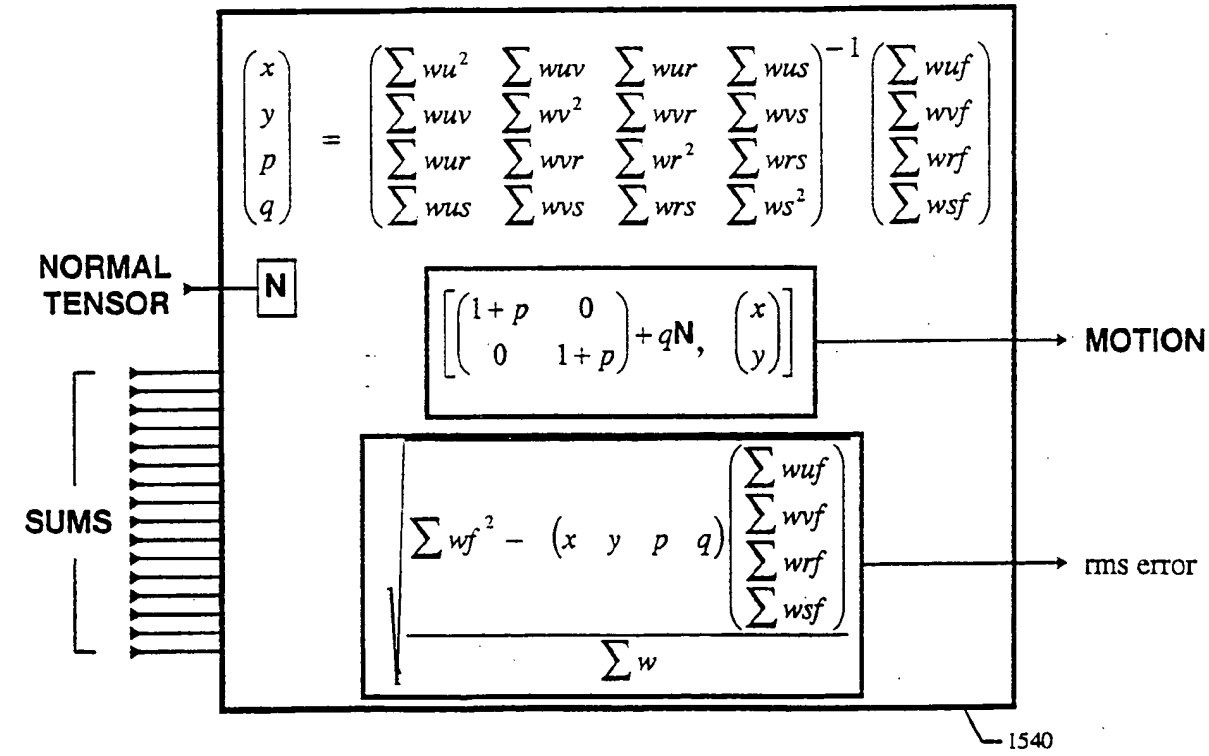

Figure 22d

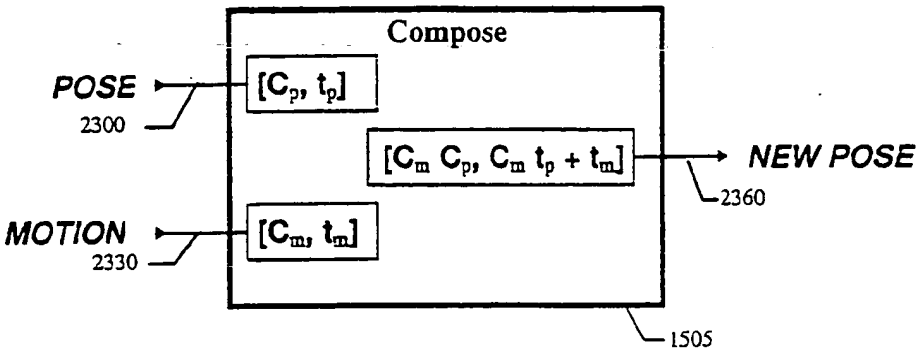

Figure 23

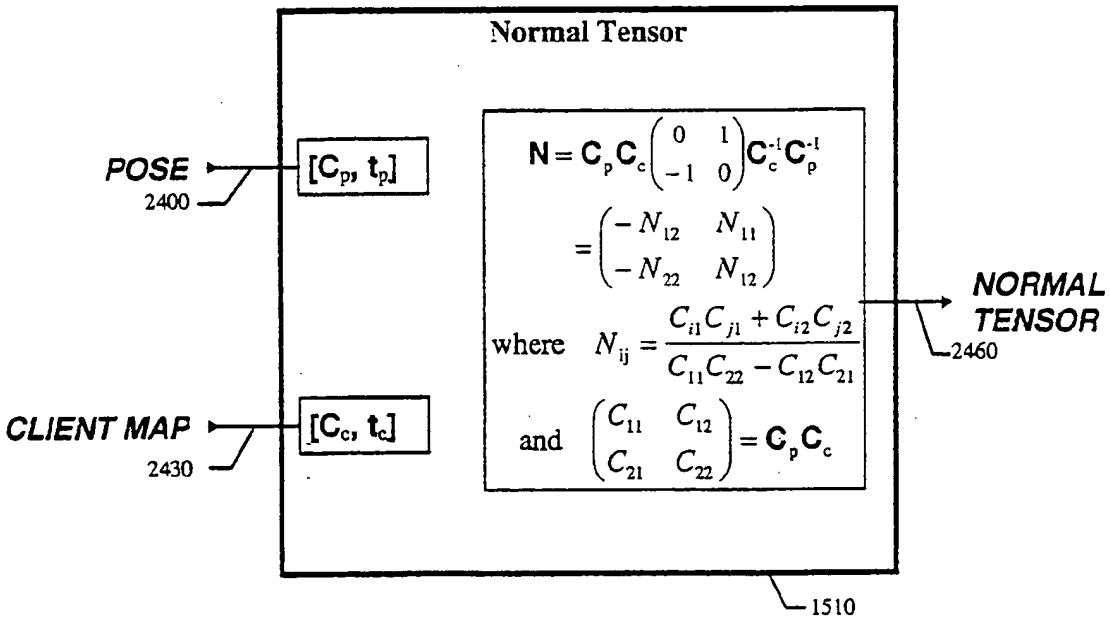

Figure 24

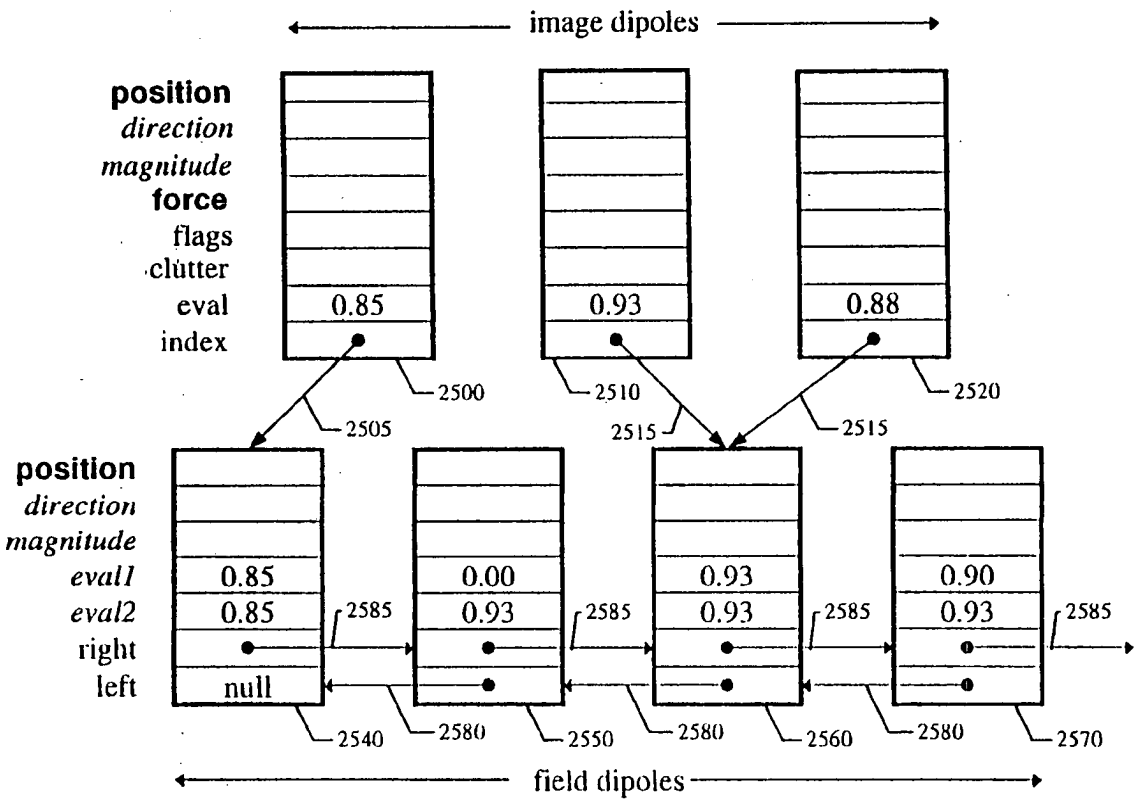
image dipoles
position
direction
magnitude
force
flags
clutter
eval
index
0.85
0.93
0.88
2500
2510
2520
2505
2515
2515
position
direction
magnitude
eval1
eval2
right
left
0.85
0.85
null
0.00
0.93
0.93
0.93
0.93
0.90
0.93
2585
2585
2585
2585
2540
2580
2550
2580
2560
2580
2570
field dipoles

Figure 25

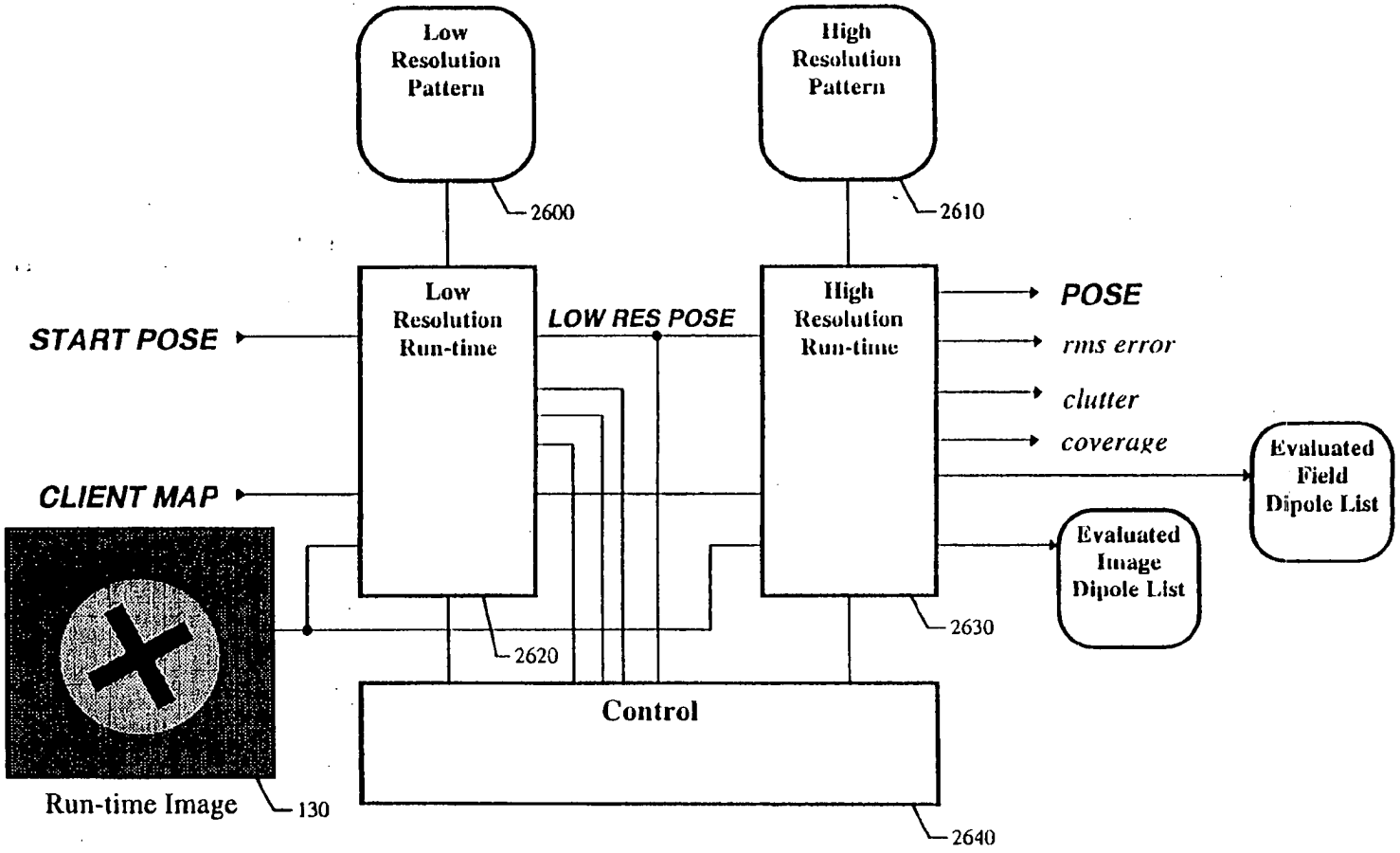
Low Resolution Pattern
2600
High Resolution Pattern
2610
START POSE
Low Resolution Run-time
LOW RES POSE
High Resolution Run-time
POSE
rms error
clutter
coverage
CLIENT MAP
Evaluated Field Dipole List
Evaluated Image Dipole List
2620
2630
Control
Run-time Image
130
2640

Figure 26

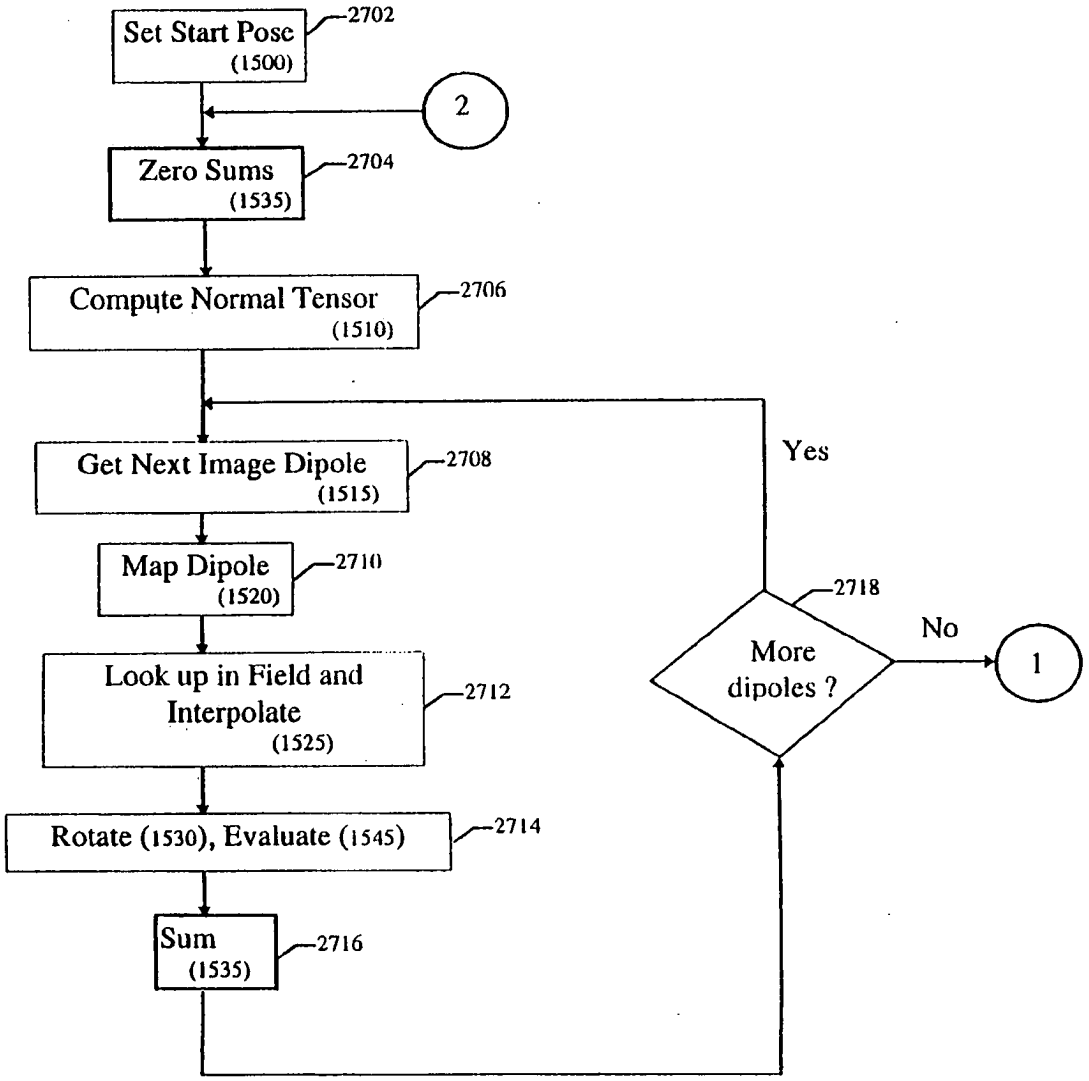
Set Start Pose
(1500)
2702
2
Zero Sums
(1535)
2704
Compute Normal Tensor
(1510)
2706
Get Next Image Dipole
(1515)
2708
Map Dipole
(1520)
2710
Look up in Field and
Interpolate
(1525)
2712
Rotate (1530), Evaluate (1545)
2714
Sum
(1535)
2716
More
dipoles ?
2718
Yes
No
1

Figure 27a

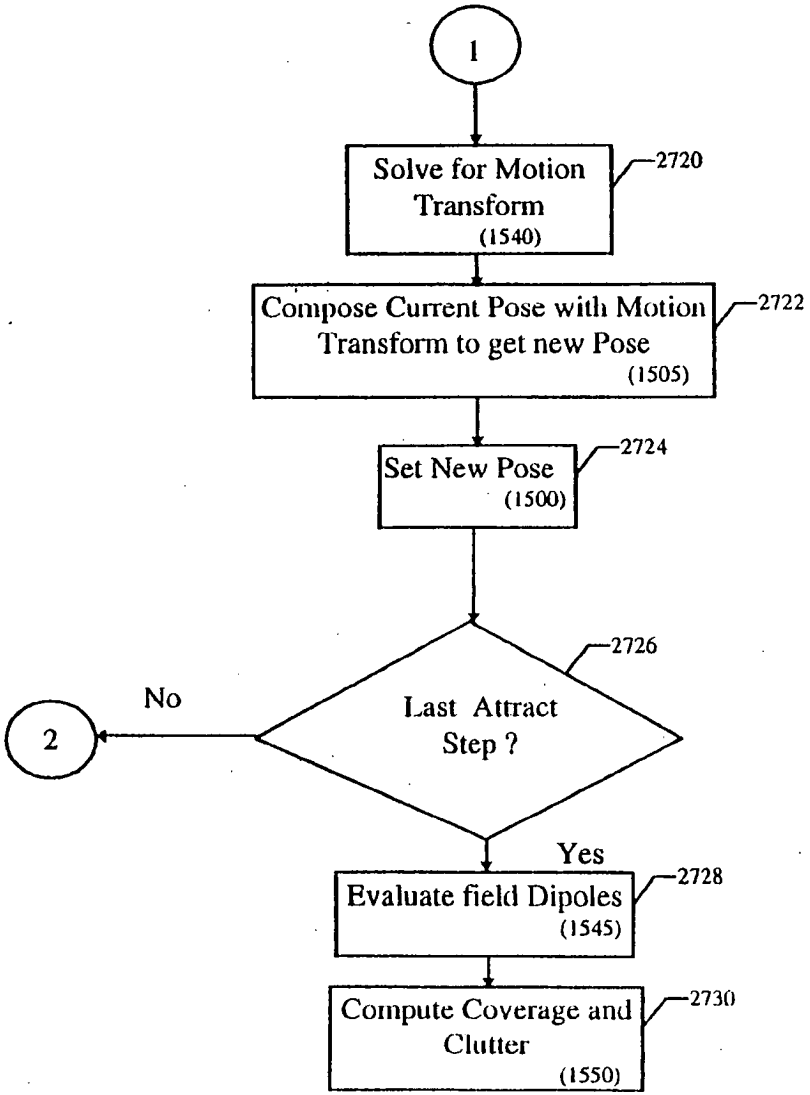
1
Solve for Motion Transform (1540)
2720
Compose Current Pose with Motion Transform to get new Pose (1505)
2722
Set New Pose (1500)
2724
Last Attract Step ?
2726
No
2
Yes
Evaluate field Dipoles (1545)
2728
Compute Coverage and Clutter (1550)
2730

Figure 27b

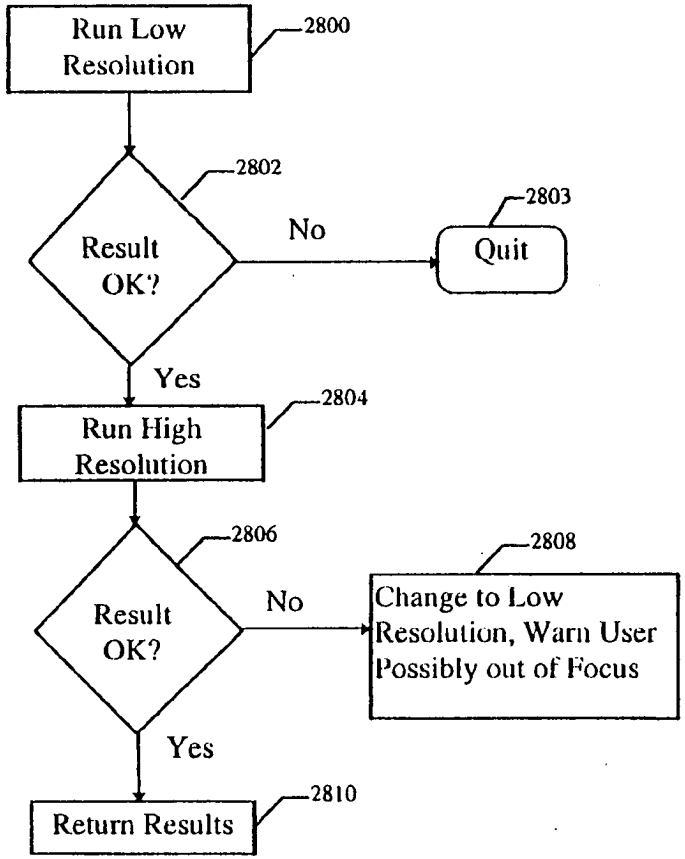
Run Low Resolution
2800
2802
Result OK?
No
2803
Quit
Yes
Run High Resolution
2804
2806
Result OK?
No
2808
Change to Low Resolution, Warn User Possibly out of Focus
Yes
Return Results
2810

Figure 28